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Effect of Bladder and Rectum Volume Standardization on Interfractional Dose in Intracavitary (Intrauterine + Paracervical) Brachytherapy of Cervical Cancer

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ABSTRACT

Purpose: This study evaluated the effect of interfractional bladder and rectum filling on HRCTV and OAR (bladder, rectum, sigmoid) doses in intracavitary brachytherapy for cervical cancer.

Methodology: A retrospective analysis was conducted on CT-simulation images of 25 patients (12 treated with T+O and 13 with T+R applicators). Patients were placed in the dorsal lithotomy position under sedation. A Foley catheter balloon was inflated with 7 cc contrast and the bladder filled with 120 cc of contrast-saline, then clamped. The patients were told what they needed to do for bowel cleaning the day before and were asked to follow these recommendations. After uterine canal measurement, a suitable T+R or T+O applicator was inserted and fixed by the radiation oncologist. For each patient, new CT-sim images were acquired in the second fraction, and new treatment plans were generated. Dose-volume histograms (DVHs) were analyzed to determine HRCTV (D100, D90) and OAR doses (2cc, 1cc, 0.1cc). Dose variations between fractions were evaluated.

Findings and Conclusion: For the T+O applicator, median HRCTV volumes were 30.76 ± 13.05 cc (first fraction) and 29.24 ± 12.91 cc (second fraction). Bladder, rectum, and sigmoid volumes in the second fraction were 151.38 ± 81.28 cc, 56.94 ± 28.44 cc, and 42.89 ± 33.46 cc, respectively. No significant differences were observed in target or OAR volumes or doses between fractions for either applicator type. Consequently, interfractional organ motion did not significantly affect dose distribution. Therefore, when bladder and rectum volume standardization is achieved, the first fraction plan can be safely used for subsequent treatments.

Keywords: *Brachytherapy; Intracavitary; Interfraction; Volume Standardization; Cervical Cancer*

INTRODUCTION

Brachytherapy (BRT) is a form of radiation therapy in which a radiation source is placed in the tumor, tumor bed, or target cavity. BRT utilizes the inverse square law, where the radiation dose is inversely proportional to the square of the distance from the source [1]. Providing the radioactive source close to the target allows very high doses of radiation to be delivered to the tumor. In contrast, doses to adjacent normal critical structures, such as the bladder and rectum, are reduced by this law. Locally advanced cervical cancer is currently treated with intracavitary and/or interstitial it is treated using a combination of brachytherapy [2].

Tandem and Ovoid (T+O) or Tandem and Ring (T+R) applicators are used in intracavitary (IC) brachytherapy treatment for cervical cancer. Since brachytherapy treatment is administered to patients in fractions, uncertainties may occur regarding the placement of the applicator and the movement of critical organs between fractions. In the literature, many studies on dosimetric differences between fractions focus not on the prescribed dose change but mostly on changes in the dose-volume histogram

(DVH) dosimetric parameters with deformable image recording (DIR) [3-5]. In the literature, studies examining dosimetric differences between fractions have investigated the effect of the applicator position and the change in dosimetric parameters [6,7]. Still, studies evaluating the changes in high-risk target volume (HRCTV) and critical organ (OARs) doses between fractions are lacking.

In addition, two of the most important factors that change the dose in cervical brachytherapy are bladder and rectal filling. In a dosimetric study by Güler O.C. et al. [8]. they showed that the combination of a full bladder and an empty rectum for planning in vaginal cuff BRT can cause significant increases in bladder doses and possibly reduce sigmoid colon and small bowel doses. However, to our knowledge, the effects of bladder and rectal filling on doses in T+O and T+R applications of cervical cancer have not been studied.

In this study, the effect of interfractional bladder and rectum filling on both HRCTV and OARs (Bladder, Rectum, and Sigmoid) doses in intracavitary brachytherapy of cervical cancer was investigated.

MATERIAL AND METHODS

The study was conducted retrospectively using computed tomography simulation (CT-sim) images of a total of 25 patients who were diagnosed with cervical cancer and completed BRT between January 2022 and July 2024 at the Department of Radiation Oncology, Istanbul University Oncology Institute. (Ethics Committee Approval: The study was approved by the Academic Coordination Community, Istanbul University Institute of Oncology (No: 2842869, Date: 29/08/2024).

Treatments of these patients were performed with a Nucletron after-loader device equipped with an HDR (high dose rate) Iridium-192 source. In this total of 25 patients, the T+O applicator was used for 12 patients, and the T+R applicator was used for 13 patients (Figure 1). A new treatment plan was made for each patient by taking new CT-sim images in their second fractions, as was done in their first fractions. In total, patients were irradiated with 5 fractions.

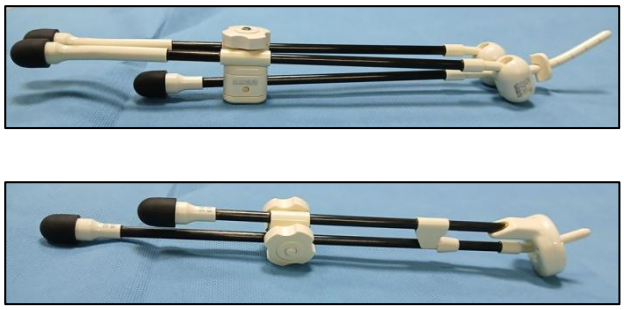

Figure 1: Tandem Ovoid (T+O) and Tandem Ring (T+R) applicators used in the study

The patients were told what they needed to do for bowel cleaning the day before and were asked to follow these recommendations. On the day of the procedure, patients were placed in the dorsal lithotomy position in the operating room. And patients were sedated. After the patients were fitted with a Foley catheter, the balloon was inflated with 7 cc of contrast and filled with 120 cc of contrast-saline combination after the bladder was emptied. The Foley catheter was clamped to ensure that the bladder remained full. After gynecological examination and measurement of the uterine canal, a T+R or T+O applicator suitable for the patient was placed in the patient by the radiation oncologist, and the applicator was fixed to the patient. To determine the position of the placed applicator, plain radiographs of the patients were taken in both AP and LAT positions with the C-arm X-ray device in the operating room. Patients were subjected to a CT simulator device (Somatom Go -Sim, Siemens, Germany), and images were taken at 1.5 mm slice thickness. CT images were obtained using Oncentra (Version 4.3, Electra Company, Stockholm, Sweden) and were transferred to the Treatment Planning System. The patient's CT images were reviewed by the Radiation Oncologist, Groupe Curie in Europe Thérapie - European Society of Radiotherapy and Oncology (GEC-ESTRO) According to the guidelines for contouring, image-based treatment planning and dose reporting [9-11], the HRCTV (taking into account the patient's MRI images) was also contoured, with the bladder, rectum and sigmoid as organs at risk. The same procedures were repeated in the second fraction for each patient.

A total of 50 plans were created for 25 patients to deliver a 5 Gy dose to 90% (D 90) of the high-risk clinical target volume (HRCTV) for both T+O and T+R. The isodose from treatment planning images obtained from the treatment planning computer in

the first and second fractions of a patient who had T+O and T+R applicators are given in Figure 2. Using the dose volume histograms (DVH) obtained in these plans, the volume doses for HRCTV (D 100 and D 90) and Bladder, Rectum, and Sigmoid (2cc, 1cc, and 0.1cc), respectively, were determined.

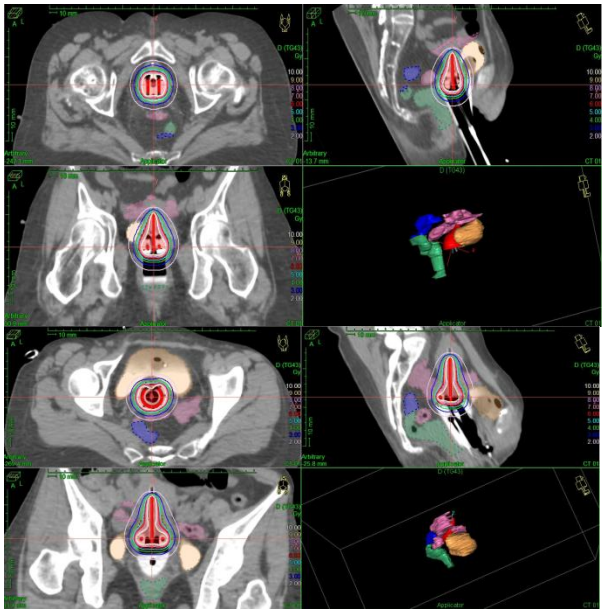

Figure 2: 1st and 2nd fraction isodoses from treatment planning images of the same patient with T+O (Top) and T+R (Bottom) applicators.

Statistical Analysis

SPSS statistical package (version 20, IBM) was used for statistical analysis. Statistical analysis was performed using a paired-sample t-test to evaluate the relationship between the dosimetric values of T+O and T+R applicators ($p < 0.05$ was considered statistically significant).

RESULTS

The HRCTV and OAR volumes defined in the treatment planning computer for the T+O and T+R applicators are given in Table 1. For HRCTV, the doses received by D100 (100% of the target volume) and D90 (90% of the target volume) volumes were determined (Table 2). For Critical Organ doses, the doses received by the bladder, rectum, and sigmoid volumes of 2cc, 1cc, and 0.1cc, respectively, were determined from Dose Volume Histograms (DVH) and statistics were performed (Table 3).

Table 1. Organ volumes for T+O and T+R applicators.

Volume (cc)	T+O 1.fr Median (± std)	T+O 2.fr Median (± std)	T+R 1.fr Median (± std)	T+R 2.fr Median (± std)	T+O	T+R
					p - value	
HRCTV	30.76 ± 13.05	29.24 ± 12.91	41.50 ± 14.94	49.78 ± 18.36	0.384	0.139
Bladder	114.44 ± 51.48	151.38 ± 81.28	106.86 ± 43.23	146.86 ± 61.13	0.094	0.074
Rectum	53.47 ± 11.62	56.94 ± 28.44	53.21 ±20.04	58.19 ± 14.15	0.712	0.439
Sigmoid	43.48 ± 18.37	42.89 ± 33.46	33.61 ± 20.22	40.04 ± 25.75	0.399	0.560

$p < 0.05$ statistically significant

Table 2. D100 and D 90 doses for HRCTV

HRCTV	T+O 1.fr Median (± std)	T+O 2.fr Median (± std)	T+R 1.fr Median (± std)	T+R 2.fr Median (± std)	T+O	T+R
					p - value	
D_{100} (Gy)	3.35 ± 0.41	3.38 ± 0.26	3.20 ± 0.35	3.19 ± 0.34	0.817	0.918
D_{90} (Gy)	5.05 ± 0.23	5.02 ± 0.08	5.24 ± 0.20	5.11 ± 0.07	0.322	0.065

$p < 0.05$ statistically significant

Table 3. OAR doses for D 90: 5 Gy

Organ At Risk	Dose to OAR	T+O 1.fr Median (± std)	T+O 2.fr Median (± std)	T+R 1.fr Median (± std)	T+R 2.fr Median (± std)	T+O	T+R
						p - value	
Bladder	Bladder D2 cc	3.36 ± 0.60	3.23 ± 0.74	3.03 ± 0.55	3.06 ± 0.50	0.597	0.887
	Bladder D1 cc	3.69 ± 0.63	3.75 ± 0.44	3.34 ± 0.58	3.35 ± 0.51	0.718	0.951
	Bladder 0.1 cc	4.54 ± 0.73	4.42 ± 0.69	4.03 ± 0.73	4.05 ± 0.54	0.534	0.916
Rectum	Rectum D2 cc	2.16 ± 0.62	2.41 ± 0.73	1.88 ± 0.63	2.07 ± 0.68	0.186	0.396
	Rectum D1 cc	2.46 ± 0.72	2.72 ± 0.82	2.12 ± 0.75	2.29 ± 0.76	0.21	0.509
	Rectum D0.1 cc	3.15 ± 0.94	3.37 ± 0.99	2.61 ± 1.05	2.77 ± 0.91	0.331	0.672
Sigmoid	Sigmoid D2 cc	1.95 ± 0.81	1.59 ± 0.78	2.21 ± 0.75	2.42 ± 0.72	0.14	0.329
	Sigmoid D1 cc	2.19 ± 0.92	1.78 ± 0.90	2.46 ± 0.83	2.82 ± 0.84	0.535	0.255
	Sigmoid D0.1 cc	2.72 ± 1.15	2.22 ± 1.15	3.11 ± 0.97	3.33 ± 0.89	0.255	0.467

$p < 0.05$ statistically significant

DISCUSSION

In the study, in order to ensure standardization between fractions, the rectums of the patients were emptied before the treatment and their bladders were filled with 120 cc as a standard. It was observed that there was no statistical difference between the rectum and bladder volumes obtained from the planning CTs taken for the first and second treatments (Table 1).

This standardization is an important parameter that ensures that the positions of the T+O and T+R applicators do not change too much between fractions.

In our study, treatment plans were made on the first and second treatment planning CTs to determine the effects of this standardization on target and OAR doses between fractions. When the doses given in Table 2 and Table 3 are examined; in patients who were applied with T+O and T+R applicators, no statistical significance was found for HRCTV, Bladder, Rectum, and Sigmoid between the first and second fractions.

Chakraborty S. et al. (6) studied the magnitude and effects of interfraction variations in organ doses in a study conducted by taking CT images in two fractions using a T+O applicator for 44 patients. Factors such as tumor regression and organ deformation during the period from the beginning of the treatment to the end of the treatment lead to dose variations between fractions. In this study, changes of up to 30 cm^3 were observed in bladder volume between two fractions, but these changes were not found to be statistically significant. The magnitude of change in rectal volume was quantitatively less between the two fractions and was statistically insignificant. However, in a significant number of patients, when no new planning was made, the second fraction reported that there may be a higher dose of the OAR, which may be due to organ deformation and/or changes in applicator placement/geometry. In their study, although no standardization of patients' rectum and bladder volumes was performed, the importance of this standardization was emphasized as a result of the study. They stated that since most of the dose changes in HDR brachytherapy are uncontrollable, imaging in each fraction is necessary to calculate OAR doses correctly.

In the study conducted by Davidson et al. [12], they evaluated whether the special three-dimensional (3D) plans created for the first application could provide similar dose distributions in subsequent applications. For a total of 27 patients, tandem and ovoid (TO) applicators were applied to 12 patients, or tandem and ring (TR) applicators were applied to 15 patients according to clinical requirements. CT scans were performed after each application and special plans were created for each application. The dose parameters of the organs for the second application were compared with the doses predicted in the first plan. The study showed that significant dose increases were observed in organs such as the rectum and bladder when a single plan was used. The increase in critical organ doses, especially in patients who underwent TR, was found to be statistically significant. In patients who underwent TO, individual differences were observed in critical organ dose values; doses increased in some patients and decreased in others. In this study, the authors filled the bladder with 30 cc of standard sterile water for standardization of bladder volumes but did not perform any application for rectal volume standardization. As a result, it was concluded that treatment plans should be re-made for each application and that using a single plan throughout the treatment period may increase the doses given to the organs.

In the dosimetric study conducted by Güler et al. [8], vaginal cuff they showed that the combination of a full bladder and an empty rectum for planning in BRT can result in significant increases in bladder doses and possibly reduce sigmoid colon and small bowel doses. They also suggested that adequate bowel preparation may be dosimetrically sufficient without the need to fill the bladder before each therapeutic session. The authors applied standardization for rectum and bladder volumes in the study, but the study was conducted for cylinder application in endometrium brachytherapy. The design of the T+O and T+R applicators used in our study is different. Depending on whether the bladder and rectum are full or empty, it may cause different target and critical organ doses than the cylinder applicator.

In addition, the presence of a rectum refractor in both T+O and T+R applicators may explain the fact that rectum doses are not dosimetrically different. For critical organ volumes to be the same before treatment, patients are asked to have bowel cleansing, and the bladder balloon is filled to 120 cc as a standard during application, and the fact that there is no statistical difference in terms of dosimetric in planning can be attributed to the similarity of critical organ volumes. In other words, it can be said that standard preparation is necessary for patients for critical organs before treatment.

CONCLUSION

We examined the effect of rectum and bladder volume standardization on target and OAR doses between fractions. Thanks to this standardization, we saw that there was no significant difference in target and OAR doses between fractionations. As a result, we recommend that the first treatment plan be used in subsequent treatments when rectum and bladder

volume standardization is achieved. But, further studies with a larger patient group are needed.

Conflict of Interest

There are no conflicts of interest and no acknowledgements.

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